REMARKS

The Office action dated October 1, 2002 and the cited references have been carefully considered.

Remarks Concerning Amendment to the Specification and Certain Claims

The specification and certain claims have been amended to change "alkali-earth" to – alkaline-earth — to correct the misspelling of this term, the latter is the correct name for the metals of Group IIA of the Periodic Table. No new matter has been added. All of the occurrences of "alkali-earth" in the claims also have been corrected to read – alkaline-earth --.

Status of the Drawings

The proposed correction to Figure 1 was disapproved. The Applicants submit herewith a correction to Figure 1, wherein the y-axis reads –lumens per watt (lpw)--, as the Examiner suggested. This correction is believed to have overcome the objection.

Status of the Claims

Claims 1-38 are pending. Claims 26-38 are canceled pursuant to an earlier restriction requirement. Claims 39-46 are new, reciting subject matter already disclosed in original claims 4, 6, 15, and 17. No new matter has been added. Therefore, claims 1-25 and 39-46 are pending in the current prosecution.

Claims 7-11 and 18-22 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form. The Applicants wish to thank the Examiner to indicate that claims 7-11 and 18-22 would be allowable. Claims 7 and 18 have been rewritten in independent form to include all of the limitations of the respective base claims. Claims 8-10 depend from claim 7, claim 11 depends from claim 10, claims 19-21 depend from claim 18, and claim 22 depends from claim 21. Therefore, claims 8-11 and

19-22 need not be amended. Claims 7-11 and 18-22 are in condition for allowance. Early allowance of these claims is respectfully requested.

Claims 2, 5, 13, and 16 are objected to for failing to further limit the subject matter of a previous claim. Claims 1, 3, 12, and 14 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Zettl et al. (U.S. Patent 6,057,637; hereinafter "Zettl") in view of Hsu et al. (U.S. Patent 6,333,598; hereinafter "Hsu"). Claims 23-25 are rejected under 103(a) as being unpatentable over Zettl in view of Hsu and further in view of Lynn (U.S. Patent 6,294,867). The Applicants respectfully traverse all of these objections and rejections for the reasons set forth below.

Claim Objection

Claims 2, 5, 13, and 16 are objected to under 37 C.F.R. § 1.75(c) as being of improper dependent form for failing to further limit the subject matter of a previous claim. Specifically, in objecting claims 2 and 13, the Examiner asserted that "it is well known that an oxygen-containing compound of alkali-earth metal is synonymous with an alkali-earth metal oxide." Office action, page 3 (emphasis added). The Applicants respectfully traverse this assertion because an oxygen-containing compound is not synonymous with an oxide. There are many oxygen-containing compounds of a metal that are not an oxide of the same metal. For example, phosphate (PO_4^{3-}), carbonate (CO_3^{2-}), nitrate (NO_3^-), sulfate (SO_4^{2-}), organic acid salts (carboxylates, such as oxalate ($C_2O_4^{2-}$), acetate ($CH_3CO_2^-$), etc.), to name a few, are not oxide. The Applicants disclose examples of oxygen-containing compounds in paragraph 20 that are not oxide. Therefore, claims 2 and 5 further limit the subject matter of claim 1 from which they depend, and claims 13 and 16 further limit the subject matter of claim 12 from which they depend. Withdrawal of this objection is respectfully requested.

Claim Rejection Under 35 U.S.C. § 103(a)

Claims 1, 3, 12, and 14 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Zettl in view of Hsu. The Applicants respectfully traverse this rejection because a combination of Zettl and Hsu does not teach or suggest all of the elements of claims 1, 3, 12, and 14.

"[T]he legal conclusion of obviousness [under 35 U.S.C. § 103(a)] requires that there be some suggestion, motivation, or teaching in the prior art whereby the person of ordinary skill would have selected the components that the inventor selected and used them to make the new device." *C.R. Bard, Inc. v. M3 Systems, Inc.*, 48 U.S.P.Q.2d 1225, 1231 (Fed. Cir. 1998). Thus, in order for the prior art to render the claimed invention obvious, all of the elements thereof must be taught or suggested in the prior art. "What must be found obvious to defeat the patentability of the claimed invention is the claimed combination." *The Gillette Co. v. S.C. Johnson & Son, Inc.*, 16 U.S.P.Q.2d 1923, 1927 (Fed. Cir. 1990).

"To establish *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art." "All words in a claim must be considered in judging the patentability of that claim against the prior art." MPEP § 2143.03 (8^{th} ed., Aug. 2001).

Zettl discloses a field emission electron source consisting of only carbon nanotubes or boron carbon nitride nanotubes suspended in a binder. Hsu discloses thin-film edge emitter consisting of alkali metals (Li, K, Na, Rb, Cs); alkaline earth metals (Mg, Ba, Sr, Ca); transition metals, such as Y, Zr, Th, their alloys; their carbides, and nitrides; noble metals, such as Pt, Pd, Au, Ir, Os; and other transition metals, such as W, Mo, Ni, Ti, Cr, and V (column 7, lines 17-22 and 34-43). Hsu does not teach or suggest <u>oxygen-containing compounds</u> of alkaline-earth metals, as recited in claims 1, 3, 12, and 14. Disclosing the metals, as Hsu does, is not the same as teaching or suggesting oxygen-containing compounds of the metals because the electronic properties of metals are very much different from those of their oxygen-containing compounds, which electronic properties influence the operation of the electron emitter in a non-obvious way. "The need for specificity [of the cited prior art] pervades [the] authority [of Section 103(a)]." *In re Lee,* 61 U.S.P.Q.2d 1430, 1433-34 (Fed. Cir. 2002). Here, Hsu never suggests, and there is no evidence that Hsu even contemplates oxygen-containing compounds. Thus, a combination of Zettl and Hsu does not teach or suggest an electro emitter comprising carbon nanotubes and oxygen-containing compounds of alkaline-earth metals, as recited in claims 1, 3, 12, and 14.

Since a combination of Zettl and Hsu does not teach or suggest all of the limitations of claims 1, 3, 12, and 14, these claims are patentable under 35 U.S.C. § 103(a) over Zettl in view of Hsu.

Claims 23-25 are rejected under 103(a) as being unpatentable over Zettl in view of Hsu and further in view of Lynn. The Applicants respectfully traverse this rejection because a combination of Zettl, Hsu, and Lynn does not teach or suggest all of the limitations of claims 23-25. (The Applicants respectfully point out that, on page 7 of the Office action, the Examiner rejected claims 23-35, but, in fact, he meant to reject claims 23-25.)

"To establish *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art." "All words in a claim must be considered in judging the patentability of that claim against the prior art." MPEP § 2143.03 (8^{th} ed., Aug. 2001).

As pointed out above, a combination of Zettl and Hsu does not teach or suggest an electron emitter comprising carbon nanotubes and <u>oxygen-containing</u> compounds of alkaline-earth metals, as recited in claim 12. Therefore, adding Lynn to show a disclosure of a gas discharge lamp containing a background gas, such as argon, still does not produce all of the limitations of claims 23-25.

Since a combination of Zettl, Hsu, and Lynn does not teach or suggest all of the limitations of claims 23-25, these claims are patentable under 35 U.S.C. § 103(a) over Zettl in view of Hsu and Lynn.

In view of the above, it is submitted that the claims are patentable and in condition for allowance. Reconsideration of the rejection is requested. Allowance of claims at an early date is solicited.

Respectfully submitted,

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Schenectady, New York
December 3, 2002

ATTACHMENT

VERSION OF PARAGRAPHS WITH MARKINGS TO SHOW CHANGES MADE

Paragraph 8:

-- In general, the present invention provides a composition for electron emitters or cathodes of gas discharge devices that can overcome many disadvantages of cathodes of prior-art devices. In the present disclosure, "electron emitters" and "cathodes" are used interchangeably to mean devices, apparatuses, or structures that are capable of providing a stream or a burst of free electrons. The composition of the present invention comprises a mixture of carbon nanotubes and oxygen-containing compounds of [alkali-earth] alkaline-earth metals. Typically, these oxygen-containing compounds of [alkali-earth] alkaline-earth metals are [alkali-earth] alkaline-earth triple oxide. Such an [alkali-earth] alkaline-earth triple oxide has been used as a coating on the cathode coils of fluorescent lamps to produce a stream of electrons in a thermionic process. The mixture of carbon nanotubes and [alkali-earth] alkaline-earth triple oxide may be coated on a filament of a metal or a metallic compound having a low work function to form a cathode of a gas discharge device. The composition of the present invention offers a comparable electron current at a lower cathode temperature; thus, helps to reduce the amount of energy expended in maintaining the cathode temperature. Furthermore, the resistance of carbon materials to sputtering in a high vacuum environment offers a reduction in the background gas pressure in gas discharge devices and an accompanying increase in luminous output. --

Paragraph 9:

-- In another aspect of the present invention, a fluorescent lamp has a cathode the surface of which is deposited with a mixture of carbon nanotubes and an [alkali-earth] alkaline-earth triple oxide. The fluorescent lamp has a background pressure of less than about 0.3 kPa. --

Paragraph 10:

-- In still another aspect of the present invention, a method for making a cathode of a gas discharge device comprises the steps of providing an amount of carbon nanotubes and

an amount of oxygen-containing compounds of [alkali-earth] alkaline-earth metals in proportions such that an electron emission from the carbon nanotubes is substantial in relation to the total quantity of electrons emitted from the cathode; mixing the carbon nanotubes and the oxygen-containing compounds of [alkali-earth] alkaline-earth metals to form a mixture; providing an electrically conducting cathode structure; depositing the mixture on the cathode structure; and converting the oxygen-containing compounds of [alkali-earth] alkaline-earth metals to [alkali-earth] alkaline-earth metal oxides. --

Paragraph 11:

-- In still another aspect of the present invention, particles of a metal catalyst are mixed and dispersed in the mixture of oxygen-containing compounds of [alkali-earth] alkaline-earth metals before the mixture is applied on the cathode structure. The oxygen-containing compounds of [alkali-earth] alkaline-earth metals are then converted to [alkali-earth] alkaline-earth metal oxides. Carbon nanotubes are subsequently grown on the dispersed metal catalyst particles within the coating layer of the cathode structure. --

Paragraph 14:

-- The present invention provides a composition for cathodes of gas discharge devices, and more particularly, for fluorescent lamps. The composition of the present invention comprises a mixture of carbon nanotubes and oxygen-containing compound of [alkali-earth] alkaline-earth metals. Typically, the oxygen-containing compounds of [alkali-earth] alkaline-earth metals are [alkali-earth] alkaline-earth metal oxides. In a conventional fluorescent lamp, a stream of free electrons is liberated from the cathode, migrates to the anode, and ionizes a gas at a very low pressure in the process. The cathode is typically a coiled filament of a metal, such as tungsten, coated with a triple oxide of calcium, barium, and strontium that have low work functions. During operation of the fluorescent lamp, an amount of about two watts of electrical energy is supplied to the cathode material to heat it to a very high temperature, typically exceeding 1000 ^{0}C, to liberate the electrons from the coated filament. In the well-known mercury fluorescent lamp, a small amount of mercury is contained in the lamp to provide the discharge. In addition a background gas is necessary to reduce the required open circuit voltage for starting the discharge and to lessen the severity of a bombardment of the cathode by high-speed ions, which would damage and

shorten the life of the cathode. A rare gas such as argon or a mixture of argon and krypton or neon is used as the background gas at a pressure of about 0.3-0.5 kPa. The Figure shows the luminous output of krypton-filled fluorescent lamps measured as lumens per watt ("lpw") as a function of krypton gas pressure. It is evident that the typical background pressure chosen to minimize the effect of damaging high-speed ions does not provide the optimum luminous output. Therefore, the lamp would be more energy-efficient if a cathode material could be used at a lower background gas pressure without being damaged. The composition of the present invention offers the promise of achieving this condition because of the resistance of carbon nanotubes to sputtering and evaporation at very high temperatures. Furthermore, it was estimated that the electric field at the tips of the carbon nanotubes could be intensified by a factor of at least 1000 because of the very small diameters of these nanotubes. Therefore, the composition of the present invention can provide an electron current comparable to that generated from conventional triple oxide-coated cathodes at a lower temperature and a lower cathode fall due to a lower cathode potential. Cathode fall or cathode fall voltage is the potential difference between the arc stream and the cathode. Both a lower cathode temperature and a lower cathode fall contribute to increasing the energy efficiency of the gas discharge device. Moreover, a lower cathode temperature would increase the life of the cathode because of a lower evaporation rate of the triple oxide emission material. It is estimated that the rate of evaporation of the triple oxide emission material is reduced by about 50 percent for every decrease in the cathode temperature of about 30-50 ^{0}C. --

Paragraph 17:

-- A mixture of the present invention was made with 25 % (by volume) of carbon nanotubes and 75 % (by volume) of a conventional [alkali-earth] alkaline-earth triple carbonate. A small amount of a temporary binder, such as a resin or a starch, may be advantageously added into the mixture. The exact quantity of the temporary binder is not critical. The mixture was deposited by spraying on a coiled cathode of a conventional T8 fluorescent lamp (General Electric Company, Cleveland, Ohio) and the [alkali-earth] alkaline-earth carbonates were converted to [alkali-earth] alkaline-earth oxides in a non-oxidizing atmosphere as is well known in the art. The coiled cathodes having the coating layer of carbon nanotubes and [alkali-earth] alkaline-earth metal oxides were installed in conventional T8 fluorescent lamps. Twenty-four such lamps were produced for testing. In

addition, twenty-three T8 fluorescent lamps also were made using the conventional [alkali-earth] alkaline-earth metal oxide emission mixture without carbon nanotubes for comparative testing. Cathode fall, cathode temperature, lamp voltage, and lamp current were measured for each fluorescent lamp. The result of the average and standard deviation for each of the measured parameters is shown below. --

Paragraph 18:

-- The cathode fall, cathode temperature and lamp voltage for the lamp of the present invention are lower than the corresponding parameters of the prior-art lamp, indicating that it is easier to liberate electrons from the cathodes of the lamps of the present invention. The twenty-degree reduction from the cathode temperature of the prior-art lamp is significant in prolonging the life of the cathode in view of the estimate that the evaporation rate of the [alkali-earth] alkaline-earth emission mixture is reduced by about 50 percent for every 30-50 ^{0}C of cathode temperature. --

Paragraph 19:

-- In another aspect of the present invention, the cathode coated with a mixture of carbon nanotubes and [alkali-earth] alkaline-earth triple oxide is installed in a fluorescent lamp. Carbon nanotubes provide a portion of the electrons required for generating and maintaining the discharge, thus lessening the requirement on the [alkali-earth] alkaline-earth triple oxide emission mixture. Therefore, the temperature of the cathode may be reduced and the life of the cathode may be extended. And since the carbon nanotubes can help to provide a comparable electron current at a lower open circuit voltage, the background gas pressure in the fluorescent lamp may be reduced to achieve a higher luminous output. Background gas pressure may be advantageously reduced to about 0.1-0.2 kPa according to the Figure to achieve an optimum luminous output in a krypton-filled fluorescent lamp. Similarly, the background gas pressure may be reduced for lamps filled with other rare gases. --

Paragraph 20:

-- A cathode of the present invention for a gas discharge device may be made by a process comprising the step of (1) providing an amount of carbon nanotubes and an amount of oxygen-containing compounds of [alkali-earth] alkaline-earth metals in proportions such that an electron emission from the carbon nanotubes is a substantial portion; such as at least 10 percent, preferably at least 20 percent, more preferably at least 50 percent, and most preferably at least 80 percent; of the total number of electrons emitted from the cathode; (2) mixing the carbon nanotubes and the oxygen-containing compounds of [alkali-earth] alkaline-earth metals to form a mixture; (3) providing an electrically conducting cathode structure such as a sleeve, a stick, a coil, a coiled coil, or a triple coil; (4) depositing the mixture on the cathode structure; and (5) converting the oxygen-containing compounds of [alkali-earth] alkaline-earth metals to [alkali-earth] alkaline-earth metal oxides to form a finished coating layer comprising carbon nanotubes and [alkali-earth] alkaline-earth metal oxides. The oxygen-containing compounds of [alkali-earth] alkaline-earth metals may be selected from the group consisting of carbonates, nitrates, oxalates, citrates, and acetates. The proportion of carbon nanotubes in the finished coating layer may be from about 0.1 percent by volume to about 95 percent by volume, preferably from about 5 percent by volume to about 90 percent by volume, more preferably from about 20 percent by volume to about 90 percent by volume, and most preferably from about 30 percent by volume to about 90 percent by volume. The deposition of the mixture of carbon nanotubes and oxygen-containing compounds of [alkali-earth] alkaline-earth metals on the cathode structure may be carried out by painting, dipping, spraying, or electrophoresis. The conversion of oxygen-containing compounds of [alkali-earth] alkaline-earth metals to [alkali-earth] alkaline-earth metal oxides is preferably done in a non-oxidizing atmosphere at a temperature and for a time sufficient to substantially complete the conversion. Typically, a temperature in the range from about 1000 ^{0}C to about 1700 ^{0}C is sufficient for this conversion. More typically, the temperature is in the range from about 1200 ^{0}C to about 1500 ^{0}C. --

Paragraph 21:

-- In another aspect of the present invention, the oxygen-containing compounds of the [alkali-earth] alkaline-earth metals are mixed with particles of a metal catalyst to form a mixture. A small amount of a temporary binder, such as an epoxy resin or a starch, may be added in the mixture to help its adherence to the cathode structure. Such a temporary

binder is typically decomposed or burnt off during a subsequent firing of the coated cathode. The mixture is deposited on the cathode structure by painting, dipping, spraying, or electrophoresis. The coated cathode is then fired in a non-oxidizing atmosphere to convert the oxygen-containing compounds of [alkali-earth] alkaline-earth metals to [alkali-earth] alkaline-earth metal oxides. Carbon nanotubes are then formed on the catalyst particles dispersed within the layer of [alkali-earth] alkaline-earth metal oxides by any cracking and pyrolyzing process mentioned above. The finished cathodes are installed in gas discharge devices by any well-known method to provide an increase in efficiency thereto. –

VERSION OF CLAIMS WITH MARKINGS TO SHOW CHANGES MADE

1. (Amended) A composition for electron emitters of gas discharge devices comprising a mixture of carbon nanotubes and oxygen-containing compounds of [alkali-earth] alkaline-earth metals.

2. (Amended) The composition according to claim 1 wherein said oxygen-containing [alkali-earth] alkaline-earth metals are [alkali-earth] alkaline-earth metal oxides.

4. (Amended) The composition according to claim 3 wherein said diameter is [preferably] in a range from about 1 nm to about 100 nm[, more preferably from about 1 nm to about 50 nm, and most preferably from about 1 nm to about 20 nm].

5. (Amended) The composition according to claim 2 wherein a proportion of said carbon nanotubes in said mixture of carbon nanotubes and [alkali-earth] alkaline-earth metal oxides is in a range from about 0.1 percent by volume to about 95 percent by volume.

6. (Amended) The composition according to claim 5 wherein said proportion is [preferably] from about 5 percent by volume to about 90 percent by volume[, more preferably from about 20 percent by volume to about 90 percent by volume, and most preferably from about 30 percent by volume to about 90 percent by volume].

7. (Amended) A composition for electron emitters of gas discharge devices comprising a mixture of carbon nanotubes and oxygen-containing compounds of [alkali-earth] alkaline-earth metals, wherein said carbon nanotubes are produced by a catalytic cracking and pyrolyzing of hydrocarbons.

12. (Amended) A gas discharge device comprising an electron emitter which comprises an electrically conductive material coated with a mixture of carbon nanotubes and oxygen-containing compounds of [alkali-earth] alkaline-earth metals.

13. (Amended) The gas discharge device of claim 12 wherein said oxygen-containing compounds of [alkali-earth] alkaline-earth metals are [alkali-earth] alkaline-earth metal oxides.

15. (Amended). The gas discharge device according to claim 12 wherein said diameter is [preferably] in a range from about 1 nm to about 100 nm[, more preferably from about 1nm to about 50 nm, and most preferably from about 1 nm to about 20 nm].

16. (Amended) The gas discharge device according to claim 13 wherein a proportion of said carbon nanotubes in said mixture of carbon nanotubes and [alkali-earth] alkaline-earth metal oxides is in a range from about 0.1 percent by volume to about 95 percent by volume.

17. (Amended) The gas discharge device according to claim 16 wherein said proportion is [preferably] from about 5 percent by volume to about 90 percent by volume[,, more preferably from about 20 percent by volume to about 90 percent by volume, and most preferably from about 30 percent by volume to about 90 percent by volume].

18. (Amended) A gas discharge device comprising an electron emitter which comprises an electrically conductive material coated with a mixture of carbon nanotubes and oxygen-containing compounds of [alkali-earth] alkaline-earth metals, wherein said carbon nanotubes are produced by a catalytic cracking and pyrolyzing of hydrocarbons.

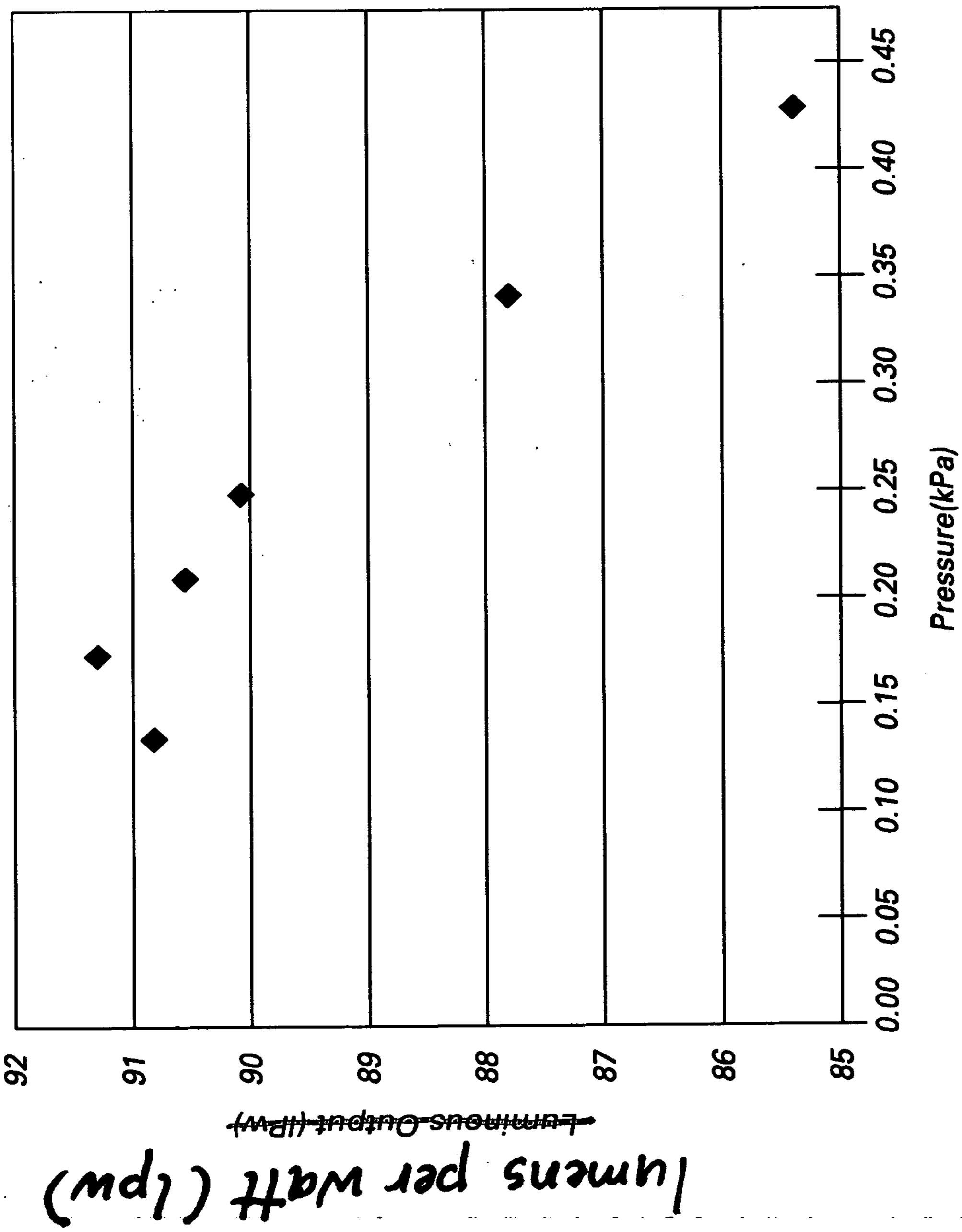
92
91
90
89
88
87
86
85
~~Luminous Output (lPW)~~
lumens per watt (lpw)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Pressure(kPa)

FIG.1